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AN ENERGY SELF-SUFFICIENT SPACE AND WATER HEATING RETROFIT PROJECT

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AN ENERGY SELF-SUFFICIENT SPACE AND WATER HEATING RETROFIT PROJECT

Prepared by

Russell R. Hansen
715 West Pine
Lewistown, MT 59452

March, 1982

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
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RAE Program
Energy Division, DNRC
Capitol Station
32 S. Ewing
Helena, MT 59620

Final Report

An Energy Self Sufficient Space and Water Heating Retrofit Project

by
Russell.R. Hansen

I. Objective

The major energy consumers for most homes in Central Montana are water heating and space heating. Self sufficiency in these areas would relieve the burden of obtaining, and paying for dwindling and ever more expensive energy commodities currently being used, i.e. petroleum, coal, electricity. For homes on small lots within city limits self sufficient electric projects may not be possible. However, solar and wood heat contributions are frequently possible. In order to establish that self sufficiency using solar water heating, solar greenhouse space heating and woodstove backup heating is possible in a Central Montana city a combination project was proposed. The multiple energy systems are deemed necessary to provide maximum security for a family's energy needs by limiting reliance on one source.

This 70 year old house retrofit project applies the use of a) an attached solar, greenhouse with water in 500 one gallon plastic jugs as a heat storage medium; b) a woodstove with both a blower system that can direct heat to a 7 ton rock storage area and a hot water extraction system to supply hot water to the water heater during the coldest months and c) a solar hot water heating system using a liquid transfer medium.

The solar greenhouse system is designed to supply at least 38% of the home heating needs during the coldest mohth of the Central Montana year, January. Likewise the solar hot water system will supply at least 60% of home water heating needs during this period.

II. Project Implementation

1. Project planning and equipment acquisition. The planning effort necessary to commense the project involved utilization of a number of sources to include the following books. The Solar Greenhouse Book by James C. McCullagh, a Rodale Press Publication; Low Cost Passive Solar Greenhouses, a Design and Construction Guide for the National Center of Alternative Technology, NCAT, by Ron Alward and Andy Shapiro; Fundamentals of Solar Heating, January 1978 a correspondence course prepared by the U.S. Department of Energy; and Installation Guidelines for Solar Domestic Hot Water Systems in One and Two Family Dwellings prepared by the U.S. Department of Housing and Urban Development Office of Policy Development and Research in cooperation with the U.S. Department of Energy. (This publication was obtained from DNRC.)

For construction details a two volume set of Fundamentals of Carpentry by Walter E. Durbahn, 4th edition, were utilized; and The Solar Catalog by the Solar Components Corporation manufacturers of Sunlight® glazing panels and products was useful for the purpose of determining proper selection of various solar items.

Numerous other solar publications were consulted during many months prior to submission of the grant, such as "Mechanics Illustrated" and similar magazines featuring articles on solar projects.

Weatherstripping and insulation information was obtained from experience with a Montana Power Company interest free loan, one year prior, involving the insulation of the basement of the house as well as information from several government leaflets i.e. "Caulking, the Push Method for Fast Simple Caulking" by NCAT and Montana Energy Saving Handbook for Homeowners by James W. Morrison, distributed by the Department of Natural Resources and Conservation.

Outside assistance was determined necessary particularly after commencement of the project thus a local consultant was contacted on several occasions in reference to specific construction problems and design problems related to the greenhouse and particularly in relation to the home built solar collectors for the domestic hot water system. Mr. Bud Barta was the consultant locally. (He has extensive knowledge in solar design and has conducted workshops and has an extensive personal library of all facets of alternative energy technology. He has provided a three week intensive energy training session by NCAT for Action and he has designed and led construction for large greenhouses for HRDC and has built or consulted on several solar collector projects and smaller greenhouse projects. During 1977 to 1980 he was technical director for the New Western Energy Show with duties including training, designing displays, andconsulting for the general public on energy matters, designed domestic hot water systems, leading greenhouse and collector workshops. 1972 to 1975 his formal education was obtained from Devry Institute where he gained an electrical engineering degree.)

In discussing planning it should be mentioned that much information was acquired during the process of obtaining price estimates on all products that were to be used in the project. These prices were obtained from a multitude of sources and the major suppliers were identified based on either quality of the product or the cost of the product or both.

The general suppliers of equipment used in the system consisted of several sources to include those listed in exhibit 33a and 33b of the original grant proposal.

The following changes should be made in these exhibits:

8. Clements
2317 Santa Fe Drive
P.O. Box 1436
Pueblo, Colorado 81002

12. Dover Construction Co.
620 Crowley Avenue
Lewistown, Montana 59457

The following additions should be made:

15. E.J. Bartell's Co.
1724 King Ave. West
P.O. Box 1138
Billings, Montana 59103

16. Chet Brown and Sons
306 5 Ave. south
Lewistown, Montana 59457

17. Fry Plumbing and Heating
418 W. Broadway
Lewistown, Montana 59457

18. Fleet Wholesale Supply
320 E. Main
Lewistown, Montana 59457

In reference to majoe components of the project, the following are considered. Three heat motors Model 50 PoR Mark VI and accompanying mounting sets; the flat Crystalite reinforced fiberglass with tedlar finish from the major fiberglass distributor called Clements located in Pueble, Colorado; the 80% sunscreen curtain for the greenhouse to be used during the summer to block excess light from entering the greenhouse as well as two minimum/maximum Taylor thermometers; one alarm kit and a Taylor hygrometer from California Greenhouse Controls Corp., one hot water cylinder and a special two speed blower were obtained via Dover Construction Co., Lewistown; the plenum used on top of the woodstove for collecting heat and subsequent ducting heat to the house and to the rock storage was built by Chet Brown and Sons of Lewistown. Copper foil used to construct the absorber surface of the domestic hot water system collector was obtained from Sunset Solar Construction, owner Dick Dill, Stevensville. Thermolock R tape and two 4x8 sheets of one inch thick duct board were obtained fuom E.J. Bartells Co., Billings for the domestic hot water system collector. Space blankets for night curtain for the greenhouse were obtained from REI Cooperative Seattle, Wash; thinsulate insulation for the night curtain for the greenhouse fuom Frostline Inc. from Boulder, Colorado; teflon film for use in the domestic hot water system solar collector was obtained from Sun Resources Marketing, California.

A 65 gallon electric solar hot water heating tank by Ford; a DT 70 Differential Controller by Delta T; a Grunfos 20-42 pump; an Extrol Solar S15 expansion tank; American airpurger; two American air eliminator vents; a Hawthorne electric digital thermometer monitor and sensors; an isolation meter by Dodge products and a urothane exterior pipe insulation for the domestic hot water system were all obtained from Solar Component Corp., Manchester, New Hampshire.

Problems encountered during the planning and procurement stage; It should be mentioned that a product obtained from California Greenhouse Supply, a beŀl system kit which was assembled when received had an identifiable problem witn the connection of the high voltage wire to the low voltage transformer. The electrical inspector identified the problem and stated that he would contact the manufacturer reguarding the problem and encouraged myself to correct the problem with the addition of a box with knockouts to enclose the above mentioned wiring. Obtaining the Crystalite reinforced fiberglass glazing was initially difficult due to the original identification of a supplier, namely Triple I Co., Salt Lake City, Utah with whom we communicated on numerous occasions. Finally after a period of two to three months we were able to determine that they were unable to obtain the product for us and we then contacted Lasco Company, the manufacturer of Crystalite, directly and they refered us to Clements of Pueble, Colo. Clements provided excellent service and the Crystalite was obtained through telephone ordering and UPS delivery. And finally a problem was encountered in attempting to obtain the exact amount of square footage of teflon film for the domestic hot water system. The sourde, Sun Resource Marketing, Anaheim, California, was courteous to send us the exact footage which was 12 feet by 48 inches of teflon film .001 inch thickness, however this would not be a recommended source in the future since usually the teflon film is supplied in a minimum of 100 foot rolls. The company also normally does not deal in the supply of material to individual users.

2. System Installation. Approximate date for initiating the work was 15 April 1981 and approximate date of finishing is 20 March 1982. Since actual time spent was entirely spare time on the part of myself and my wife and since that time was not recorded on a daily basis it is impossible to provide the exact amount of time spent. An estimate of approximately 600 hours of personal labor has been made.

The problems encountered in the installation and construction phase seem numerous, the following seem to be the most pronounced problems:

a. The completion of the rock storage unit found that calculations were incorrect and the number of bond beam blocks and the amount of rock actually used was considerably less, in fact nearly half the volume initially expected. Therefore instead of 7 ton of rock, 4 ton was utilized and instead of 34 bond beam black, approximately 20 bond beam blocks were actually utilized. Therefore the heat storage capacity of the unit is considerably less than initially estimated and planned.

b. Several problems with material and construction design were identified upon consultation with Mr. Bud Barta. First was the utilization of the styrofoam insulation as planned in addition to the six inch fiberglass insulation. The white styrofoam insulation planned will apparently not hold up to moist conditions. Since the greenhouse will pose moist conditions, this suggestion was taken and rather than the white, the blue tongue and groove, 2 x 8 panel, styrofoam insulation was used instead. And instead of putting the styrofoam insulation on the inside wall of the construction it was placed on the outside walls. Since this decision was made after the installation of the foundation it was found that the allignment of the greenhouse wall with the house wall on the outside was no longer ideal and therefore the greenhouse is jutting out approximately three to four inches from the adjacent house wall on the west side of the greenhouse.

c. The all weather wood foundation has a potential problem in that this may pose a problem because of the nature of a foundation. It is virtually impossible to waterproof thus moisture condensation as well as leakage may render the fiberglass insulation less desirable in terms of performance, due to the possible decrease in insulation value. Since this remains to be seen it is perhaps a problem that should be monitored in the future with core samples if possible during the course of the next five years.

d. Another problem identified by Mr. Bud Barta was to redesign the glazing system of the green house also the sill upon which the glazing would be sitting. He recommended that the sill be slanted so that the moisture would not settle on the flat sill. Therefore the sill is slanted perpendicularly to the angle of the studs that were holding the glazing. The angles are approximately 55°. Secondly, the glazing studs were found to be a potential problem in that the design called for 2x4 material which may have been too weak for the roof load that the 2x4's would be carrying. Therefore a substitution of 2x6 lumber was made.

e. The materials for the domestic hot water heating system collectors was found to be inappropriate. Mr. Bud Barta again recommended major changes in the selection of materials for this portion of the project. The materials initially chosen were not as fire resistant as are desirable for a solar hot water heating collector. Materials were in essence very combustable i.e. some portions were exposed wood, the insulation was a bat type fiberglass insulation and no protection for the glazing from the inside was provided, a single walled glazing was to be used. Additionally, the use of a product called Solaroll which is an EPDM rubber was originally planned. Mr. Bud Barta, representatives of Solar Component Corporation, and a DNRC representative all advised that the use of Solaroll can be incorporated into a DHW system. However, the application may not be maximally efficient, therefore it was recommended that Solaroll mat could be used more effectively for some applications such as heating swimming pools.. Thus, the decision was made to build the absorber surface of the collector from metal and add a second glazing layer. One half inch copper pipe spaced approximately 5 inches apart was soldered to copper foil and a thin layer of teflon film was used to provide for stagnation safety.

f. The obtaining of DHW pipe insulation was found to be extremely difficult in this location since there was only one dealer for DHW (commercial) systems identified in Lewistown. Several were available outside the Lewistown community who were very difficult to contact via telephone. The exterior pipe insulation was omitted from the initial planning therefore it was found to be needed toward the end of the construction process and obtaining it therefore was deemed to be necessary on an expedient basis. Therefore after trying with local plumbing supply shops for 3 weeks (one shop is even carrying DHW systems) we were unable to obtain even product information from them. Thus the insulation was ordered from the Solar Corporation.

3. System Testing Modification

The system was and will be tested via the use of the monitoring equipment obtained for the purpose of monitoring the project, that is the thermometers, humidity meter, and the isolation solar meter. The primary means of testing the system is with the Hawthorne electronic digital thermometer which has the capability of using eight sensors. For the project we are currently using only six sensors. Sensor location appears to be very important for determining the performance of the various systems. Sensor number one was attached to the upper portion of the Ford Solar hot water heater. This is a very difficult installation since there is no easy place to attach the sensor. The sensor is merely attached as close to the tank as possible on the hot water pipe coming out of the tank.

The second sensor was placed at the bottom of the tank and this sensor is placed at the cold water pipe coming into the bottom of this tank.

The third sensor is in a room in the house to give a house temperature on a continuous basis.

The fourth sensor was buried in the rock storage unit approximately two feet below the top surface of the rock.

The fifth sensor was placed on the solar collector. The optimal location seems to be on the pipe running between the two collectors so that during operation an optimal reading is obtained. It is thought that when the system is not operating the temperature can still be obtained, if it were placed at the bottom near the outlet the temperature would be accurate during operation but would not be accurate when the system was not in operation.

The sixth sensor was placed on the top exterior surfaae of the hot water cylinder (that is located on the inset portion to the rear of the All Nighter Wood Stove).

By juggling the sensors to various locations the areas described were found to be the optimal locations. By watching the Hawthorne electronic digital thermometer it has been possible to determine the optimal operation of the systems. It was found that during usage of large volumes of water such as when doing dishes or bathing the thermosyphon syste, would actually dilute the temperature of the water leaving the hot water heating tank if the valves are not closed on the thermosyphen system. (On the thermosyphoning system the plumbing was initially placed directly beneath the tempering valve which is of course on the outgoing hot water supply coming from the hot water heating tank. This placement dramatically influenced the diluting of the hot water with cold water if the valves were open on the thermosyphon system and therefore the plumbing was altered with the thermosyphon system coming into the second opening on the top of the Ford water tank, which is the outlet for the temperature pressure relief valve and now also the inlet of the thermosyphon system. With this placement the diluting factor is still present but is definitely diminished.)

The Hawthorne electronic digital thermometer was originally felt to be only necessary for use in the monitoring phase of the project but upon using the thermometer it was discovered to be an essential part of the fine tuning of the systems and in fact ensuring optimal operation is potentially achieved from all of the systems. Another modification was that of the recording sheets where the monitoring of these systems are recorded. The modification was simply the addition of other data. The major headings remain which were in the initial grant proposal, however additional information was added to some of them. The following information was added: the isolation meter reading consists of not only the direct solar isolation in BTU's in morning, noon and evening but also diffused radiation reaching the meter morning, noon, and evening and also these readings are taken both inside and outside of the greenhouse as originally planned. A second new recording was added for that of the operation of the blower to provide information on the performance of the blower in terms of the relationship between outside temperature and internal house temperature as well as rock storage temperature and greenhouse temperature. Recording whether the vents are open or closed to the rock storage unit is also made. A third new recording is the pressure of the domestic how water system which is made at least once daily. Fourthly recordings are also made in terms of whether or not the valves on the thermosyphon system are open or closed. These recordings are made three times daily morning, noon, and evening. These recordings are used as a tool for managing the thermosyphen system since it is easy to forget if the valves are open or closed.

4. System Performance, System performance of course is difficult to assess at this early date. Only some initial readings for the past 15-20 days are recorded on the monitoring sheets mentioned above in which storage tank top temperature, storage tank bottom temperature, house temperature, rock storage temperature, operation of the blower and vents, the solar collector temperature, the hot water cylinder temperature, whether or not the stove is operating, whether or not the vents are open, pressure gauge of the solar hot water heating system, greenhouse temperature, greenhouse humidity, the outside temperature, and the isolation meter readings have provided us with limited preliminary data and seem to indicate positive performance except for the rock storage system. I will procede through the systems to describe the performance for which the data is mostly subjective at this time.

1) The solar collector system appears to be heating water on various warm and cold days during the last of February 1982 and beginning of March 1982. The highest temperature recorded at the solar collector thus far was 136° when the outside temperature was recorded as 64° at noon on the fifth of March. The storage tank at the bottom was recorded to be 98° at noon on the fifth of March. Therefore it appears that the solar collector system is working, however efficiency is difficult to determine since family do dwell in the home all day long and hot water is used throughout the day.

Include forms

2) The greenhouse system also appears to be working very adequately and perhaps very well in fact. It was observed on one sunny day that the temperature outside was 10° at noon and the greenhouse reached approximately 80° inside. This is with approximately 500 water bottles for heat storage on the inside. When the temperature in the greenhouse goes above 70° it appears to add sufficient heat to the house to alleviate the use of the electric baseboard heaters used for home heating. It is found that with the basement door leading to the greenhouse and the top half dutch door open from the greenhouse into the dining room a very good exchange or circulation of air is made within the house using this passive system of heating. It has been observed in the greenhouse that in the first 15 days of March the minimum temperature recorded was 46° and the minimum humidity recorded was 55%. It should be noted that only a few plants are housed in the greenhouse at this time, the humidity is relatively constant and seems to fluxuate only with the greenhouse temperature. It is anticipated that humidity will increase with the addition of plants.

3) In terms of glazing performance of the greenhouse the isolation meter has been used to record the regular and the direct radiation both through the glazing and outside of the greenhouse and diffused radiation has also been recorded by simply shading the solar cell on the meter by holding a finger approximately two inches from the cell and making sure that the cell is completely shaded. The reading appears to indicate that the solar radiation arriving inside the solar greenhouse is approximately 1/2 to 2/3 that of the radiation arriving on the outside of the greenhouse. In terms of the diffused radiation however (or reflected radiation) it appears that the radiation diffused inside the greenhouse is roughly 90% of that reflected or diffused outside the greenhouse. In relationship of the observation we have several sunflower plants growing on an experimental basis just to determine how well the radiated light appears to be doing for the plants. The plants do appear to be normal color and therefore it is assumed that most plants should perform relatively well inside the greenhouse.

4) In terms of the thermosyphen system from the hot water extraction cylinder on the woodstove which leads to the solar hot water heating tank it has been observed that the thermosyphen system increases the overall temperature of the water stored in the hot water tank quite well. As mentioned previously in this report the thermosyphen system does tend to dilute the hot water that is being removed from the tank for example when the dish sink is being filled or the bathtub is being filled with water. This, however, seems to be a minor problem and is not expected to effect comfort in terms of the usage of the hot water. A possible relationship has been noticed between the temperature of the storage tank and that of the extraction cylinder. As the storage tank temperature increases so does the extraction cylinder's temperature. The highest temperature this far recorded for the extraction cylinder during those morning, noon, and evening recording times which happened to coincide with the operation

of the extraction cylinder was 143°. Normally the operation temperature is in the neighborhood of 116° to 120°. The storage tank temperature is currently being maintained at approximately 115° . This household has found the temperature of 115° to be an optimal temperature in terms of energy savings. The temperature is adequate for hand dish washing and for bathing functions (particularly when considering young children to reduce the chance of scalding should a child enter a bath that has not been diluted with cold water). Dilution with cold water is unnecessary and therefore it is assumed to be a more efficiant usage of hot water.

5) As mentioned previously the rock storage system appears to not be working as planned. The exact reason for this is not determined thus far. The nature of the problem is that it does not seem possible to increase the temperature of the rock storage unit via the duct work system and the blower system that has been installed. A possible reason for this problem is that the rock used in the rock storage unit bin is sometimes less than 3/4 inch in diameter. When ordering the rock 3/4 inch was specified however upon delivery the rock was found to contain many pieces less than 3/4 inch in diameter. Therefore possibly there is not enough air space for quick circulation of air through the rock storage unit as desired. The purpose of the rock storage unit was to provide an emergency back up of heat should the temperatures in the greenhouse fall below a minimum for example 36°F at which time the thermostatically operated bell alarm system whould sound the alarm alerting us that the greenhouse temperature had fallen below this danger point at which time the woodstove would be stoked, and the duct opened into the rock storage unit and the door of the rock storage unit into the greenhouse as well as the door from the basement would allow heated air to flow into the greenhouse. It was thought that the blower system would facilitate the flow of air from the rock storage unit into the greenhouse, however this also does not appear to be working as originally planned. Since the operation of the blower does not seem necessary except during extremely cold outside temperatures i.e. 15°F or less, the blower has been used to pump air into the rock storage unit only a limited amount of time. During January 1982 in particular few recordings were made.

6) In terms of the greenhouse performance it appears to be very acceptable in that a cherry tomato plant was brought into the greenhouse in mid September 1981 and continued to survive and produce tomatoes until January 1, 1982 when the temperature in the greenhouse dropped below the freezing point for the first time and the tomato plant died as a result of the freezing. The outside temperature although we did not record the temperature was reported on the radio as 10° below zero. It was noted throughout the fall of 1981 that the temperature inside the greenhouse stayed about 30° warmer than the outside temperature, however again it should be noted that throughout that time, fall of 1981 and January 1982, the vents on the greenhouse were not completely weatherstripped and therefore cold air leakage into the greenhouse would account for some of the temperature fluctuations. It is believed that since the weatherstripping was completed

the performance i.e. temperature inside versus temperature outside is perhaps greater than 30° and infact on March 2, 1982 when the noon temperature was 18° F the minimum temperature in the greenhouse was recorded to be 54°F. Therefore a slightly greater temperature difference of perhaps 36° might be expected.

7) The night curtain was not completed until late February 1982 and installation was not until March 1982 during which time temperature outside began to moderate enough so that utilization of the night curtain was no longer essential, however it should assist in keeping the internal temperature slightly above those that have been experienced. It is felt however that the night curtain would definitely assist during the cold months like January when temperatures are reaching 20 to 30° below zero at night and it is definitely felt that the night curtain will moderate the temperature inside the greenhouse sufficiently to alleviate almost entirely the chance for freezing temperatures inside the greenhouse.

5. System Cost

Date	Description of expense/ vendor	$ amount	
3/18/81	Building Permit, City of Lewistown	50.50	
4/25/81	Foundation, UBC	570.31	
5/ 2/81	Anchor bolts, Pacific Iron	5.22	
5/14/81	Rock, Casino Creek	49.05	(nonreq.)
6/ 3/81	Staples, nails, UBC	11.05	
6/ 3/81	Bond beam blocks, Lewistown Sales	32.30	
6/19/81	Space blankets, REI	78.50	
6/19/81	Heat motors, John Hoffman	214.87	
6/19/81	Netting, thermometers, alarm system California Greenhouse	146.60	
6/20/81	Paint, OK Hardware	12.99	
6/20/81	Paint, Coast to Coast	12.99	
6/23/81	Cuprinol, OK Hardware	25.98	(nonreq.)
6/23/81	Paint, maxi seal, thermometer, sensors Solar Components	498.50	
6/26/81	Wood, UBC	208.05	
6/26/81	Nails, wood, Econo	218.84	
6/27/81	Copper pipe, Hawk	33.00	
6/27/81	Caulk, Lewistown Lumber	4.44	
6/27/81	Roofing, Econo	15.66	
6/30/81	Insulation, Econo	22.32	
6/30/81	Rock, Casino Creek	43.60	
7/ 1/81	Bolts, UBC	10.77	
7/ 6/81	Sewing of netting, California Greenhouse	12.20	
7/ 6/81	Bolts, UBC	3.12	
7/11/81	Insulation, Econo	233.44	
7/12/81	Warranty Hawthorne Digital Thermometer, Hi Square	19.75	(nonreq.)
7/13/81	Wood, UBC	147.52	
7/13/81	Nails, Econo	3.20	
7/18/81	Nails, insulation, Econo	63.51	
7/20/81	Caulk, adhesive, Econo	16.14	
7/21/81	Flashing, wood, Econo	16.74	
7/22/81	Nails, caulk, UBC	4.29	
7/25/81	Caulk, nails, insulation, Econo	17.18	
7/31/81	Caulk, nails, Econo	5.10	
8/ 1/81	Nails, UBC	1.60	
8/ 3/81	Crystallite, Clements	38.67	
8/ 3/81	Thermolock, E.J. Bartells	25.30	
8/ 4/81	GAF Plastic UBC	10.29	
8/ 6/81	Wood, UBC	21.82	
8/13/81	Edge seal, Solar Components	75.00	
8/15/81	Plastic cement, UBC	4.70	
8/20/81	Cuprinol, Lewistown Hardware	8.50	
8/20/81	Weatherstrip, Coast to Coast	7.78	
8/21/81	Wood, hinges, threshold, UBC	32.99	
* 7/30/81	Crystalite, Clements	308.02	
7/ 7/81	Hot water cylinder and blower, Dover Construction	190.00	

Date	Description of expense/ vendor	$ amount	
8/22/81	Wood, Econo	63.83	
8/22/81	Thinsulate, Fabric Line	87.50	(nonreq.)
8/27/81	JM MAD Board, E.J. Bartells	31.20	
8/29/81	Caulk, UBC 11.88	11.88	
8/29/81	Caulk, Econo	10.40	
8/31/81	Caulk, UBC	14.42	
9/ 2/81	Solar collector parts, Solar Components	627.88	
9/ 2/81	Teflon film, Sun Resources	50.00	
9/ 2/81	Copper foil, Sunset Solar	51.60	
9/ 3/81	Plemum, Brown's Plumbing	30.40	
9/ 9/81	Freight, Sunset Solar	5.85	(nonreq.)
9/ 9/81	UPS, Solar Components	28.92	(nonreq.)
9/12/81	Hinges, Lewistown Hardware	8.76	
9/12/81	Nails, wood, UBC	66.80	
9/12/81	Plywood, UBC	15.90	
9/18/81	Wood, UBC	8.40	
9/19/81	Wood, UBC	2.20	
9/21/81	Caulk, Econo	5.20	
9/24/81	Insulation, tape, pipe, Hawk	87.62	
9/24/81	CDX plywood, nails, Econo	83.20	
9/24/81	Valves, Lewistown Lumber	1.14	
9/25/81	Solder, fittings, Cenex	6.61	
9/25/81	Pipe insulation, UBC	11.80	
10/3/81	Fittings, Hawk	5.10	
10/9/81	Freight for hot water heater, Molar way	108.97	(nonreq.)
10/17/81	Caulk, thermax, closet pole, UBC	38.76	
10/17/81	Solder, fittings, propane bottle, Cenex	46.96	
10/17/81	Wood, flashing, Econo	80.25	
10/19/81	Electric permit, State of Montana	35.00	(nonreq.)
10/23/81	Wood, Econo	10.23	
10/23/81	Cloth for night curtain, Fay's Fabric	17.50	
10/24/81	Nails, screws, weatherstrip, UBC	10.40	
11/ 7/81	Stove pipe fittings, Lewistown Hardware	9.93	
11/ 7/81	Emery cloth, Cenex	1.40	
11/12/81	Solder, Cenex	11.94	
11/14/81	Rope, Lewistown Hardware	22.95	
11/14/81	Material for night curtain, Fay's Fabric	74.00	
11/20/81	Solder, Fleet	8.70	
11/20/81	Solder, Cenex	21.30	
11/28/81	Pipe, Lewistown Hardware	55.77	
11/28/81	Copper adapters, Hawk	4.00	
11/28/81	Eye bolts, tees, nails, caulk, UBC	20.85	
11/28/81	Copper fittings, Cenex	24.02	
11/28/81	Valves, UBC	40.96	
11/28/81	Solder, Fleet	8.70	
12/ 5/81	Lumber, UBC	17.60	
12/ 5/81	Pipe fittings, Cenex	24.75	
12/ 5/81	Wire, Hawk	26.46	

Date	Description of expense/vendor	$ amount
12/11/81	Cuprinol, valves, Lewistown Hardware	30.73
12/19/81	Switch, wiring, Hawk	6.45
12/19/81	Caulk, UBC	4.99
12/21/81	Copper pipe fittings, Fry Plumbing	6.90
12/21/81	Fuses, Town and Country	4.82
12/22/81	Flux, Cenex	.70
12/23/81	Copper elbow, Hawk	.56
12/24/81	Copper pipe, Hawk	5.19
	Copper pipe, Town and Country	14.25
12/28/81	Relief valve, Fry Plumbing	21.00
12/28/81	Rope, Cenex	3.50
12/28/81	Romex, adapter, Hawk	6.76
1/ 2/82	Copper pipe, elbows, Hawk	14.02
1/ 2/82	Lumber, UBC	33.46
1/ 4/82	Copper,elbows , Hawk	.56
1/ 7/82	Romex, pipe, Hawk	19.92
1/ 8/82	Hangers, UBC	2.46
1/ 8/82	Pipe insulation, plate, Coast to Coast	5.46
1/ 9/82	Pipe Coast to Coast	19.95
1/2/82	Fittings, Cenex	7.18
1/16/82	Clamps, Cenex	5.55
1/16/82	Nails, lumber, Econo	63.89
1/20/82	Lumber, Econo	8.88
1/23/82	Copper pipe, Hawk	11.22
1/23/82	Weatherstrip, Econo	68164
1/27/82	Copper coupling, Hawk	.27
1/30/82	Brackets, duct tape, threshold, UBC	15.05
2/ 6/82	Rope, bolt pulley, Lewistown Hardware	4.39
2/ 6/82	Solder, coupling, spring, Cenex	6.65
2/ 6/82	Catch, UBC	.85
2/10/82	Paint, paint thinner, UBC	12.52
2/11/82	Staples, tape, caulk, Econo	13.00
2/13/82	Wire, Rope, Lewistown Hardware	13.75
2/13/82	Pulley, Econo	1.79
2/13/82	Filon, wood, UBC	9.00
2/16/82	Copper adapters, caulk, Hawk	10.02
2/17/82	Tee, Cenex	.90
2/19/82	Paint, UBC	7.89
2/19/82	Weatherstrip, Town and Country	5.00
2/22/82	Crimps, clamps, Town and Country	2.48
2/23/82	Hygrometer, California Greenhouse	34.55
3/ 3/82	Closet pole, holders, duct tape, caulk UBC	33.38
3/ 3/82	Pipe insulation, Solar Components	59.00
3/6/ 82	Paint, Coast to Coast	19.99
3/ 5/82	Winch, Montgomery Ward	16.79
3/17/82	Sewing of night curtain, Charlies	50.00
	total	6254.72

Credits

7/6/81	REI	2.50
7/11/81	Lewistown Sales	14.25
7/13/81	Solar Components	15.50
8/22/81	UBC	.12
9/24/81	Solar Components	12.92
3/10/82	Hawk	13.20
		$58.49

Received from DNRC

5/16/81	570.31
6/19/81	1428.28
7/16/81	594.86
8/15/81	636.55
9/ /81	302.00
	3532.00

Total spent	6254.72
Credits -	58.49
Total cost	6196.23

Total cost	6196.23
Received DNRC	3532.00
	2664.23

Amount of grant remaining = 454.23

	2664.23
-	454.23
	2210.00 total cost to grantee

6. Economic Evaluation. The method to be used to evaluate the economic savings will be as follows: Using the past Montana Power Company bills which state the number of kilowats used each billing period we will compare similar months i.e. January 1981 to January 1982. After finding the difference we will calculate the savings using the current rate per kilowatt. Next year when actual temperatures will be recorded we can make sure we are comparing similar months as far as temperatures. It should be noted that this home uses electricity for all appliances as well as electric baseboard heaters. Also we will have to take into consideration that we had a baby in August 1981 and we are subsequently using more energy for washing and drying cloths.

An estimated savings of approximately 500 KWH per month appears to be realistic at present based on preliminary comparisons of representative months during the winters of 1980 and 1982. Since this estimate is for winter months the savings may be less when evaluating for an entire year however, full capacity/utilization data is not available to date.

The 500 KWH amounts to $17.25 per month (at the current $0.0345/KWH) or $207.00 per year. Thus payback time would be approximately thirty years ($6196.23 ÷ $207.00, that is: total project cost ÷ estimated annual savings).

As mentioned in the original proposal statements the cost of non-renewable energy continues to escalate plus the growing of our own produce will certainly enhance savings so that payback, as mentioned in the proposal statements, is still thought to be closer to 10-15 years.

III Conclusions and Recommendations:

The significance of the project is dealing with the concept of an attached solar greenhouse which is of course a new idea to many people in the Lewistown area and provides a demonstration project. There are two other attached solar greenhouses in the community but the purpose of this project in terms of the public availability provides a more widespread discimination about the project.

The purpose of this projeet as previously mentioned is to save energy for this household. It is also hoped to save transportation costs i.e. trucking etc. of fresh produce to Lewistown. Savings in terms of future applications for commercial as well as private greenhouses in the area may be a spin off.

It should be noted as a goal that the production of fresh produce in the greenhouse will decrease or alleviate the necessity of buying produce that has been transported to the area.

Projects are certainly feasible in the Lewistown area since Lewistown is located $47^{\circ}03'$ North latitude and $109^{\circ}27^{8}$ west longitude at an elevation of 4145 feet. This home is located at 715 West Pine Street and is situated much as houses elsewhere in Lewistown (to be specific it is 30° East of true South). This orientation is likely to decrease the efficiency by 90% but this decrease is not significant.

The solar radiation in central Montana is approximately 150 Langleys or 553 BTU's (3.69 BTU/ 1 Langley).

Since this project does utilize wood heat it should be noted that the availability of wood is excellent in this area. Some air pollution has been noted in the past, this does not seem as yet to be a significant problem and in fact this project would suggest the possibility of decreasing the need for wood heat in that solar heating via the attached solar greenhouse would provide much of the heating needs and the solar domestic hot water heating unit would provide much of the hot water even during winter months. The woodheat would be used during the night time to provide comfortable temperatures in the home.

It appears that the performance of the systems in this project are within the realm of that expected when wrutubg the proposal with the exception of the rock storage system which is not apparently accepting heat as originally was thought possible and therefore emergency heating of the greenhouse is perhaps not feasable. The reason for this is thought to be the size of the rock used in the rock storage unit.

The shortcomings of the project that come to mind relate essentially to modifications that occurred during the course of the project which ideally would have been considered at an earlier stage. During the initial review of the proposals it would be desirable to have technical assistance and expettise available, I would suggest,at the time of the reviewbng of the proposal so that major discrepensies in the proposals are identified more thoroughly than were in the case of this particular project. Items that come to mind that were a problem were i.e. the use of inappropriate insulation in terms of the insulation of the greenhouse walls using white bead styrofoam instead of a more preferable blue stryofoam which is more water resistant. Since the problem occurred and the decision was made to use the blae stryofoam, the cost literally doubled for this portion of the insulation package.

The second problem was that of the solar collector construction. Ideally the construction details mentioned in the initial grant proposal should have been identified during the review process as being inappropriate that is the materials selected for the collector to include the collector absorber surface, as well as the insulation materials were totally inappropriate for use in this domestic collector building field.

Another possible problem is the insulation used in the all weather wood foundation may have been in error that is the fiberglass batt insulation may retain moisture and it's efficiency will decrease whereas a sytrofoam insulation or equivalent should have been used, again this item could have been caught by technical representatives during the review process of the grant.

IV. Monitoring

During the five year period following the completion of the project, the following methods of monitoring the systems will be utilized:

In order to generate performance data and to provide information with which to evaluate the performance of the project for both the grantee and the department. The monitoring will consist of monitoring the greenhouse temperature at morning, noon,.and evening and recording the minimum temperature, the maximum temperature on the inside of the greenhouse likewise morning, noon, and evening temperature outside of the greenhouse will be recorded based on the maximum and minimum temperatures, as well as the noon temperature. These recordings inside and outside the greenhouse will be recorded in degrees fahrenheit based on identical Taylor minimum/maximum thermometers (the thermometer has a capacity of recording a minimum of -40° F and a maximum of 130°F as well as reading a current temperature. A Taylor wet-drybulb hygrometer will be used to monitor the humidity of the greenhouse and this recording will also be taken at morning, noon, and evening. An isolation meter will be used to record direct and diffused radiation in BTU's per square foot. The recordings will be taken at morning, noon, and evening for both direct and diffused radiation and the recordings will be taken both inside and outside for both direct and diffused radiation. These recordings are intended to provide data over the five year period on the performance of the glazing to determine if there is an overall general decline in transmission ability.

A Hawthorne digital temperature monitor model H-1640 will be used to monitor several locations at morning, noon and evening in degrees fahrenheit. Those locations are 1. the top of the storage tank for the hot water storage system, 2. the bottom of the same storage tank, 3. the house temperature, 4. the rock storage temperature, 5. the solar collector temperature, and 6. the hot water extraction cylinder temperature. Relationships between these temperatures and the various systems they are associated with will be used to identify obvious performance capabilities of the systems being monitored, the solar collector, the hot water storage tank , the thermosyphen system from the wood stove to the hot water storage tank which uses the hot water extraction cylinder at the rear of the wood stove and also the duct work system from the same wood stove which uses a plenum on the top of the wood stove in order to duct heat to various parts of the home.

Additional recordings on the monthly recording sheet which is a three page form and samples of which are attached to this final report. Additional readings included are whether or not the blower unit for the duct work system on the woodstove is in operation morning, noon, and evening as well as whether or not the vent on the duct system is open going to the rock storage bin. An additional recording pertains to whether or not the valves on the thermosyphon system are open or closed morning, noon, and evening. These recordings are made primarily to provide the users with a reminder for opening and closing the valves since this can be a problem and in addition to comments a final recording is that of the pressure gauge on the closed DHW solar heating system.

The following steps will be taken in terms of monitoring the performance of the system and providing information to the department. 1. As mentioned directly above the project systems will be monitered using the above monitoring system on the monthly forms with morning, noon, and evening readings using various monitoring equipment. This information will be made available to DNRC on required reports as well as any relationships observed based on the data recorded. 2. The second step will likewise be to provide DNRC for each reporting period, required information and analysis of the energy bills received from Montana Power Company and their relationship to overall energy savings.

V. Public availability

While making the project available to the public does not appear to be a problem at this time, it is prefered that groups or individuals be scheduled by written or telephone notice at least two to seven days in advance. Smaller groups and individuals may either contact the grantee again via written or telephone notice with one day notice or more if possible. It is understood that under some circumstances individuals may be traveling through Lewistown and may not be abel to schedule a viewing time in advance, thus the project will be made available to them if possible.

An estimated twenty-five individuals have viewed the project either in its completion stage or during the construction stage and have viewed the project favorably. Most individuals that have viewed it have been local and therefore travel has been minimal. The general response is that they are aware of the possibblity of using an attached solar greenhouse but they don't seem to understand the passive solar concepts involved and/or the potential for the passive solar types of systems. Recently a guestbook has been initiated for those individuals who have viewed the project. It should be noted that one radio interview was granted shortly after the apparent news release to the local radio station pertaining to the allotment of the grant to us, the grantees.

VI. Program Evaluation

The Renewable Energy Program under the auspices of DNRC has been a very favorable type of program and provides the opportunity of a community such as Lewistown to observe an alternative energy project. This opportunity is certainly of significance. Additionally the benefit to us, the grantee, as individuals in terms of experience in constructing and working with alternative energy sources as well as the financial aspect of adding a major contribution to our present home should not be ignored and are certainly extremely favorable aspects of the program. Suggested changes in terms of procedures were mentioned in "Conclusions and Recommendations" in that better technical review of proposals should definitely be considered and ideally implemented in order to insure maximum utilization of funds provided by the Renewable Energy Program for project of this nature. I would suggest that the Department require that the grantee provide extremely detailed information on a technical basis whether or not there are particular facets of the construction plan that need to be altered priop to the initiation of construction supplies and purchase of construction supplies.

Thank you for allowing us to participate in the excellent program. We certainly hope that this program can continue and can benefit others. We look forward to continuing to work with the Department during the ensuing five year period in terms of providing maximum information on the performance of the systems that have been purchased and the systems that have been installed.

Exhibit #33a

*
Suppliers

1. United Building Centers
403 1 Ave. South
Lewistown, Montana 59457
538-5465

2. Econo Farm and Home Center Inc.
Hwy 87 W.
Lewistown, Montana 59457
538-7666

3. Cenex
207 1 Ave. South
Lewistown, Mt. 59457
538-9414

4. Recreational Equipment Inc.
P.O. Box C 88125
Seattle, Wash. 98140
206 323-8333

5. Charlies Paint and Glass
301 W. Janeaux
Lewistown, Mt. 59457
538-9482

6. John Hoffman Co.
635 W. Grandview Ave.
Sierra Madre, Ca. 91024
213 355-9940

7. Building Inspector
City Hall
Lewistown, Mt. 59457
538-3801

8. Triple I Supply Co.
3041 S. Main
P.O. Box 15495
Salt Lake City, Utah 84115
801 487-5431

9. Kalwall Corp/Solar Div.
P.O. Box 237
Manchester, N.H. 03105
603 668-8186

10. California Greenhouse Controls Corp.
3266 N. Rosemead Blvd.
El Monte, Ca. 91731
213 283-3339

Exhibit #33b

11. Lewistown Sales Central Masonary Supplies
506 1 Ave. south
Lewistown, Montana 59457
538 8181

12. All Nighter Stove Works, West, Inc.
P.O. Box 1858
Richmond, Indiana 47374

or

Futura Energy Products
Emmett, Idaho
208 365-3518

13. Hawk Electric and Plumbing Supply Inc
406 1 Ave. south
Lewistown, Montana 59457
538- 5493

14. Casino Creek Concrete
Casino creek road
104 Cottonwood
Lewistown, Montana
538-7160

Greenhouse Monitoring

Exhibit #32a

Month	Greenhouse Temp. °F			Greenhouse % humidity			Outside Temp. °F			Insulation Meter in/out Regular			Diffused		
	min	noon	max	am	noon	pm	min	noon	max.	am	no	pm	am	no	pm
1															
2															
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Hawthorne Thermometer Monitoring

Exhibit #32b

Month	1 Storage tank top °F			2 Storage tank bottom °F			3 House Temp °F			4 Rook Storage Temp °F			Blower yes-No operating/vent op		
	am	noon	pm	am	noon	pm	am	noon	pm	am	noon	pm	am	noon	pm
1															
2															
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Hawthorne Thermometer Monitoring

Exhibit #32c

Month	5 Solar coll. Temp °F			Hot Water 6 °F from ext. cylinder			Stove operating			Valves open yes/no			Press. guage	Comments
	am	noon	pm	am	noon	pm	am	noon	pm	am	noon	pm		
1														
2														
3														
4														
5														
6														
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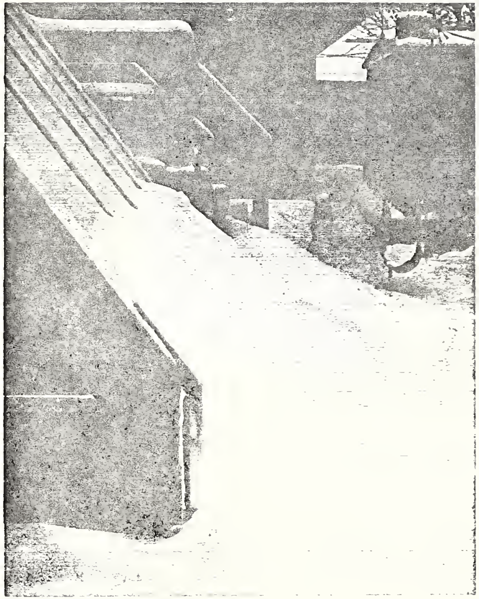
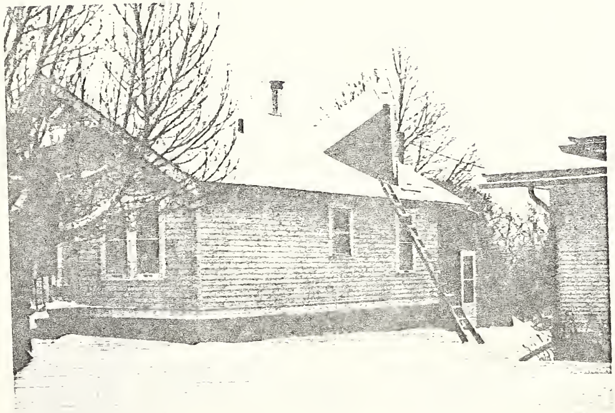
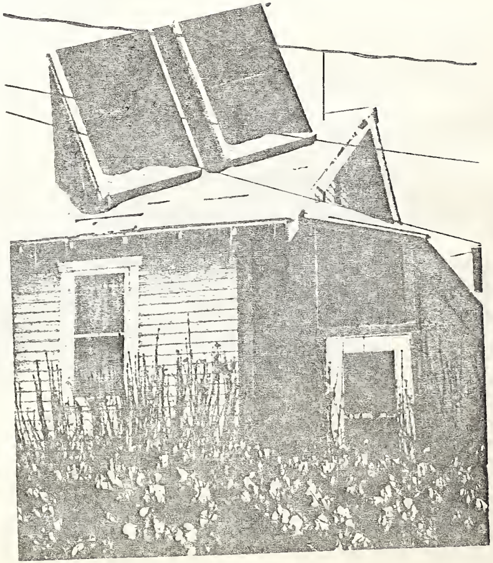
View from South-West side.
Glazing has snow on it.



Kneewall is approximately two feet high. This view is looking toward East.





Solar Collectors mounted at
60° angle and facing due south.

Note: Plumbing was not installed at the time
of the photo.

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